



# SNOW GOGGLES AND LIMITING SUNLIGHT

## LESSON OVERVIEW

### LESSON SUMMARY

Although different kinds of radiation are helpful to human activities, too much of it can be harmful. The purpose of this lesson is to illustrate the use of the scientific method to solve problems of too much radiation. By studying ancient solutions to the issue of excessive sunlight on human vision, we can better understand the process of designing solutions to similar problems for spacecraft, such as the MESSENGER mission to Mercury. Students will build snow goggles similar to those used by the Inuit people. The goggles are designed to block unwanted light, while increasing the viewer's ability to see in a bright region. Students will also create their own version of the goggles to improve upon existing designs. Students will compare the process used to invent snow goggles with that employed by the MESSENGER mission designers. As a result, they discover that the basic principles of using the scientific method for solving problems are the same, regardless of whether the exact solution to the problem is the same.

### OBJECTIVES

Students will be able to:

- ▲ Construct snow goggles to examine an ancient solution to the problem of excess sunlight.
- ▲ Explain how the scientific method can be used to solve different kinds of problems.
- ▲ Explain why excessive sunlight is a concern for the MESSENGER spacecraft.



*Figure 1. Snow goggles were used by ancient hunters as eye protection while they looked across snowy landscapes in bright sunlight in search of food. Snow goggles consisted of an opaque eye-covering made of materials such as wood, leather, whale-bone or ivory, and were attached by a string. Narrow slits or holes limited the hunters' field of view, but reduced bright sunlight so that their visibility on ice and snow was greatly improved. Today's hunters wear modern sunglasses or snow goggles often made of Polaroid lenses, which are quite effective in reducing excessive amounts of light. (Picture credit: Arctic Studies Center, National Museum of Natural History, Smithsonian Institution: <http://www.mnh.si.edu/lookingbothways>; photograph by Carl C. Hansen.)*

GRADE LEVEL  
5 - 8

DURATION  
1-2 hours

### ESSENTIAL QUESTION

How can the scientific method be used to solve different kinds of problems?



### CONCEPTS

- ▲ The scientific method can be used to solve a variety of problems.
- ▲ Sunlight is necessary for many different purposes (such as hunting or observing the properties of planets), but too much of it can be dangerous.

### MESSENGER MISSION CONNECTION

We need some sunlight to see, but too much may be harmful to our eyes. In a similar way, the MESSENGER spacecraft needs some sunlight to operate and to observe Mercury, but too much of it can heat it up and cause damage.

## WARNING

**Do *not* look directly at the Sun!**

This lesson is about the Sun and sunlight, but be sure to remind students frequently ***never to look directly at the Sun!*** Looking for even a few seconds can cause permanent damage to the eyes, and longer exposure can cause blindness. Note that sunglasses do *not* provide an adequate safeguard against looking directly at the Sun.





## STANDARDS & BENCHMARKS

### NATIONAL SCIENCE EDUCATION STANDARDS

#### Standard A1 Abilities necessary to do scientific inquiry

Identify questions that can be answered through scientific investigations: Students should develop the ability to refine and refocus broad and ill-defined questions. An important aspect of this ability consists of students' ability to clarify questions and inquiries and direct them toward objects and phenomena that can be described, explained, or predicted by scientific investigations. Students should develop the ability to identify their questions with scientific ideas, concepts, and quantitative relationships that guide investigation.

#### Standard A2 Understandings about scientific inquiry

Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models.

#### *Related Standards*

#### Standard E1 Abilities of technological design

Students should develop their abilities by identifying a specified need, considering its various aspects, and talking to different potential users or beneficiaries. They should appreciate that for some needs, the cultural backgrounds and beliefs of different groups can affect the criteria for a suitable product.

#### Standard E2 Understandings about science and technology

Many different people in different cultures have made and continue to make contributions to science and technology.



## AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, PROJECT 2061

Benchmark 4 F/2: Something can be "seen" when light waves emitted or reflected by it enter the eye – just as something can be "heard" when sound waves from it enter the ear.

Benchmark 11 B/3: Different models can be used to represent the same thing. What kind of a model to use and how complex it should be depends on its purpose. The usefulness of a model may be limited if it is too simple or if it is needlessly complicated. Choosing a useful model is one of the instances in which intuition and creativity come into play in science, mathematics, and engineering.

Benchmark 12 C/5: Inspect, disassemble, and reassemble simple mechanical devices and describe what the various parts are for; estimate the effect that making a change in one part of the system is likely to have on the system as a whole.



## SCIENCE OVERVIEW

Spacecraft need sunlight for a variety of purposes. Sunlight is emitted from the Sun, and reflected from or absorbed and later reradiated by planetary surfaces and atmospheres. All of these forms of radiation are necessary for observing the objects in the solar system and deciphering their properties. Sunlight is also useful for providing power to the spacecraft making these observations. But there are also situations when there is too much sunlight, and in some cases this can cause severe problems.

### MESSENGER Mission and Excessive Sunlight

Spacecraft use solar cells to generate electricity. However, as a spacecraft approaches the Sun, it receives more sunlight than it can handle. Smaller solar cells are not the answer, since the Sun still heats up the cells. One way to deal with the problem is to spread out the cells enough so that they can radiate their heat into space as infrared light.

The MESSENGER mission to Mercury has this problem, since it approaches the Sun to within 0.3 AU (AU = Astronomical Unit; one AU is the distance from the Earth to the Sun). The amount of sunlight to which the spacecraft is exposed depends on its distance from the Sun,  $R$ , as  $(1/R)^2$ . In other words, the MESSENGER spacecraft will be exposed to 11 times the sunlight that it would have on orbit around Earth ( $(1/0.3)^2 = 11$ ). In addition, Earth's atmosphere allows only about half of all solar radiation to pass through, so that the MESSENGER spacecraft will actually be

exposed to as much as 22 times the amount of solar radiation as it would on the surface of Earth. (Note also that spacecraft operating in orbit around Earth, but above the atmosphere, also need to worry about heat and radiation – for MESSENGER, this will just be a much greater problem.) To deal with this excess of sunlight, 70% of the area of the MESSENGER spacecraft's two solar panels is covered with mirrors, while only 30% has actual solar cells generating energy.

The MESSENGER mission designers have had to deal with excess sunlight also in another context. The spacecraft has several instruments that are used to observe the properties of Mercury and its environment. Some of the radiation – both solar radiation and radiation emitted or reflected from the planet's surface – is necessary to make the observations, but

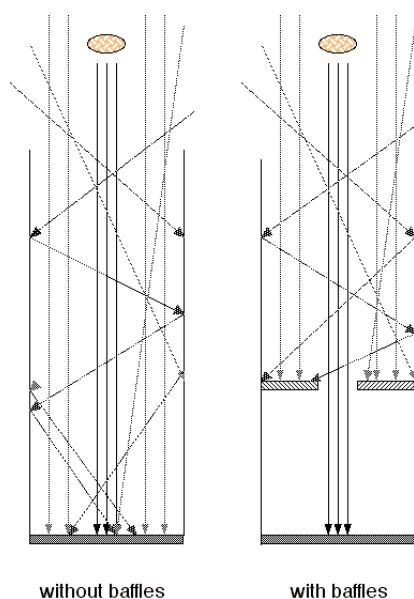


Figure 2. Without baffles, light from many directions enter the instruments and reach the detectors. By using the baffles, most of the stray light can be stopped from reaching the detectors.

too much light

can create severe problems for the sensitive instruments. To overcome this problem, the instrument designers use devices called baffles – basically fences placed inside the instruments - that stop light from unwanted directions from entering the instrument detectors (see Figure 2). In this way, only the light that is needed for observations gets to the detectors, while the baffles keep the excess light away.

### Snow Goggles

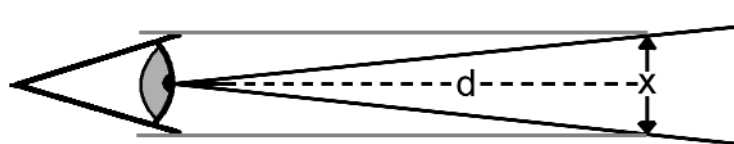
On Earth, we also encounter situations where we have to deal with excess sunlight, such as on a very bright, sunny day. In modern times, we overcome this problem by using sunglasses to protect our eyes. In the past, however, people did not have access to materials from which to make effective sunglass lenses, and they came up with other solutions.

Snow goggles are devices that have been used since ancient times by the people of northern Europe, Greenland, northern Asia and North America. The goggles were devised to reduce "snow blindness," a painful and crippling eye condition that can cause travelers and hunters great hardship, since they lose their sight temporarily, and may have permanent eye damage.

The snow goggles work by limiting the observer's field of view. Your field of view (FOV) can be defined as the angle you can see (either vertically or horizontally) without moving your eyes or your head (see Figure 3). In the horizontal direction, the edges of your FOV are commonly known as "peripheral vision."

We can limit our natural FOV by placing something in front of our eyes to reduce  $x$  (how high or how low we can see). This also gets rid of some of the unwanted light. Most snow goggles used by ancient hunters reduce only the vertical FOV significantly and just slightly affect the horizontal FOV. This is desirable so that you can look into the distance and scan a large portion of the horizon without having to move your head or your body – an important consideration especially for a hunter looking for prey in arctic, snow-covered regions.

While individual cultures developed slightly-differing designs, snow goggles share a few common characteristics: They significantly reduce the user's vertical field of view, fit fairly snugly across the eyes to eliminate peripheral light, and improve vision. The history of these devices informs current scientific research



$$\text{FOV} = \frac{x}{d} = \frac{\text{how high you can see}}{\text{distance}}$$

Figure 3. The simple formula for Field of View (FOV) – the angle a person can see without moving their eyes or their head.



and innovation both into the human need to reduce excessive amounts of light (including all forms of heat and radiation) on the eye, and into the technological need to reduce it on various instruments and devices.

### The Scientific Method in Action

In this lesson, students will use the scientific method to arrive at the idea of needing some sort of eye protection (snow goggles, for example), form a hypothesis as to how they might do that with limited materials, then construct and experiment with a potential solution. They will discuss the results of their experiments, and re-visit their original hypotheses.

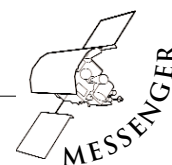
Using the scientific process, a scientist:

- 1) states a problem;
- 2) forms a hypothesis;
- 3) experiments;
- 4) observes the results of an experiment;
- 5) revises the hypothesis or concludes that it is acceptable.

Sometimes people confuse hypothesis with established theory. A hypothesis is basically a suggestion of a solution to a problem that must be tested to see whether it works or not. If the hypothesis is successful in solving the problem, it can become part of a larger knowledge base about the subject – an established, united collection of facts, which can be called the general theory explaining the properties of the subject.

For example, there is a general theory of how Mercury and the other planets in the solar system were formed. If someone asks a question related to this theory – for example, how Mercury’s high density can be explained within the theory of solar system formation – he or she can come up with a possible solution – a hypothesis. This proposed solution can be tested using various methods, such as computer simulations or observations of the properties of the planet. If the hypothesis passes all these tests, it can become part of the general theory of how the planets – and especially Mercury in this case – were formed. In fact, there are several hypotheses related to Mercury’s high density, and one of the principal science goals of the MESSENGER mission is to provide data to test which of these hypotheses might be correct.

Students will discover that the scientific method can be used to address different kinds of problems. After constructing snow goggles, students will study the problem of excess sunlight for the solar panels and the instruments on the MESSENGER spacecraft. For both the ancient arctic hunters and the MESSENGER spacecraft, the source of the problem is the same – excess sunlight. But the resulting problems created by excess light may be different. The problem of MESSENGER’s instruments being “blinded” by excess sunlight is fairly similar to the possibility of snow blindness for arctic hunters, but the concern about overheating of MESSENGER’s solar panels is





very different from problems faced by the hunters. Therefore the solutions to the problem may also vary: snow goggles are a good solution for the hunters, and analogous baffles are the solution for MESSENGER's instruments. The solution to solar panels overheating consists of spreading out the solar cells so that only 30% of the solar panels' surfaces absorb light while 70% reflect it away. In all cases, the same principle – the scientific method – is used to devise the different solutions.





## LESSON PLAN: MAKING SNOW GOGGLES

The students will make snow goggles similar to those used by ancient Inuit hunters and observe their properties. By using the scientific method to come to the idea of making the goggles, the students become familiar with the same process used by spacecraft designers.

### PREPARATION

- ▼ Conduct this activity on a sunny day. (This may not be necessary but it makes the point clearer.)
- ▼ Have students work in groups of three.
- ▼ If desired, make transparencies as well as hard copies of the student worksheets and information sheets for classroom explanations (one per student).

### WARM-UP & PRE-ASSESSMENT

1. With the whole class, conduct this brief brainstorming activity in no more than 5 minutes, to get students thinking about (and defining in their own words) the problem. (I.e., excess sunlight can cause blinding conditions that make it difficult or impossible to see well.)
2. In large letters on the blackboard or on a flipchart, make three different columns and label them:  

SUN
SUNGLASSES
HUNTERS

Have students write down on their paper anything they know or can associate with each word. Give them 2 or 3 minutes.
3. Call for the students' ideas, and write them on the board.
4. Ask students to make a connection between all three categories by asking, for example, "How are these things related?"; "Is there a problem they share in common?"; or "Can you make a sentence out of the phrases and words from each column?"

### Materials

Per student:

- ▼ 1 page of notebook paper
- ▼ Snow goggle cut-outs from Patterns A and B, preferably printed on cardstock, foam core, or cardboard
- ▼ Scissors

Per group of 3:

- ▼ 2 meter sticks
- ▼ 2 chairs
- ▼ Scotch tape
- ▼ Optional: Xacto knife, hot glue gun (only needed with foam core or cardboard)

Per class:

- ▼ One pair of sunglasses (for demonstration only)
- ▼ Blackboard or flipchart with markers



### Teaching Tip

Student answers should include the need of sunglasses to reduce bright sunlight, and that a hunter would benefit from them as well. Cue students with questions such as, "Where can you find hunters?" or (if it is a bright day): "Look outside – BUT DO NOT LOOK DIRECTLY AT THE SUN – How would your eyes feel if you had to stare out across a snow-covered field looking for something all day?" to remind them of some conditions under which hunters (or outdoor laborers and athletes) work.

### PROCEDURES

1. Discuss the problem that the students identified based on thinking about the Sun, sunglasses, and hunters in the Warm-up. Point out that they had just begun step 1 of the Scientific Process: "Stating a problem." Outline the rest of the process below, or paraphrase as needed. Using the scientific process, a scientist:

- 1) states a problem;
- 2) forms a hypothesis;
- 3) experiments;
- 4) observes the results of an experiment;
- 5) revises the hypothesis or concludes that it is acceptable.

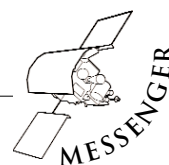
Remind the students that hypothesis is not the same as established theory. A hypothesis must be tested and accepted to become part of larger body of knowledge, the general theory of the subject.

2. Tell the students that they will use this process to solve a problem in class, and then they will be asked to solve another problem: one that has to do with traveling in space!

3. Pose the following problem to the students:

SITUATION: Imagine that you are a 19th century hunter, trying to spear a seal on the arctic ice in springtime to feed your family. Near the North Pole, where everything is covered by snow and ice, it is bright in all directions. There is so much light and glare from the sky and reflected from the snow-covered ground, that you can become snowblind.

PROBLEM: How do you get rid of the excess light you do not need, but keep the light you do, so that you can still see the seals (and so that you don't accidentally bump into a polar bear)?





4. Point out limitations, such as there being no Polaroid lenses in the 19th century, and that excess light is not a new problem. Tell students that in fact, a solution was found centuries ago by the Inuit people of North America, Greenland, Europe, and Asia.

5. Brainstorm ideas together as a class, writing them on a chart so that all can see. Choose the best educated guesses, and form one or more hypotheses, which is step 2 of the scientific process. (Possible answers: Hats that block the Sun completely; sunglasses that filter or block certain rays/colors; facial coverings to block peripheral light; tinted mirrors to reflect away some light; tents & canopies.)

6. Discuss the practicality of the ideas, in terms of whether they could be tested and proven right or wrong (i.e., whether they are falsifiable), and whether the necessary materials would be available at that time in that region. Keep a record of students' suggestions. If necessary, prompt: "If you use an eye protection device to block some light and just look through a hole you may not see well without moving your head. How can you solve this?"

7. Tell the students they will now proceed with scientific process step #3, to experiment with one of the hypothetical solutions to the stated problem. If no one suggested a solution similar to the snow goggles, you may have to introduce it here.

8. Hand out worksheets, snow goggle patterns, scissors and tape. Have students cut out and assemble snow goggles. Ensure that each group makes at least one of each pattern A and B.

### Teaching Tip

Show students how to make a slit in the goggles by folding the paper gently at the half-way point, and cutting half the slit with its other side. Note that patterns A and B look very similar but they have a different slit size (A: 5 mm, B: 7 mm). Make sure the slits are accurately cut.



9. Have students label the goggles with their names (and, if desired, a team name and colors).
10. Ask students to hypothesize as to how each pair of goggles will work, whether one version is better than the other at protecting the eyes and improving vision, and if so, under what circumstances. Have the students write their ideas on paper so that they can compare their guesses with actual observations later.
11. Have students completely read through and follow the instructions on Student Worksheet 1, conducting the experiment and filling in the data as a group, but answering questions individually. (This worksheet may also be used for assessment.)

#### Teaching Tip

Show students how to test their field of view, by ensuring that the Viewers do not move their head or eyes. Have the Experimenter hold the meter stick vertically. If the numbers are not easily readable, hold up a certain number of fingers at differing heights, and mark the stick with tape at the highest and lowest points seen by the viewer.

#### DISCUSSION & REFLECTION

1. Regroup the class to discuss the observations they made during their experiments.
2. As students contribute comments, conclude that the amount of light coming to their eyes is reduced by the goggles. How much it is reduced can be calculated, and if there are students interested in finding out how to do this, tell them they can complete student Challenge Worksheet 1 at the end of this lesson. Other students may want to estimate what fraction of the light is reaching their eyes, based on the size of the slit in the goggles. (With these goggles, about  $\frac{1}{3}$  of the light reaches their eyes, which is quite enough for a hunter to see well on snow and ice).





3. Remind students of their original hypotheses regarding the arctic hunter, and ask them to discuss the importance of light in his/her life, including length of day and night, intensity of the Sun at different times of day and year, reflection on snow or ice, etc. Ask if the students' experiments allow them to accept their hypotheses or if they need adapting.

4. Have the students describe their results and the application of their results to everyday life.

(This next section may be assigned as homework, or may be continued in a second class meeting, if more time is needed.)

5. Tell students that, as they solve the problem of reducing excessive sunlight on Earth, they have been going through the same way of thinking, that is, the same "Scientific Process," that will help them figure out how to reduce excessive sunlight in almost any situation, including in space.

6. Using the MESSENGER Information Sheet either as an overhead or as student copies, read through the description of the spacecraft and its mission.

7. Have students list similar problems that both MESSENGER and the arctic hunter might have in common. You may want to do a brief brainstorming with three columns on the board, as you did in the warm-up. Write:

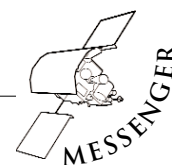
MESSENGER    SUN    ARCTIC HUNTER

on the board, and give students 2 minutes to come up with words they associate with each.

8. Call for the students' ideas and demonstrate how the class is using the same scientific process to solve a different problem. It is important to point out that the same object (in this case, the Sun) can cause many different problems and that each may require a different solution. In any case, the scientific process will guide the scientist.

A scientist:

- 1) states a problem;
- 2) forms a hypothesis;
- 3) experiments;
- 4) observes the results of an experiment;
- 5) revises the hypothesis or concludes that it is acceptable.





Assign as homework or as extra credit the following, as found on Student Challenge Worksheet 2:

**SITUATION:** The MESSENGER spacecraft flying to the planet Mercury uses solar cells to generate electricity. However, as the spacecraft gets closer to the Sun, it receives more sunlight than it can handle. Smaller solar cells are not the answer, since the Sun still heats up the cells. MESSENGER will be exposed to as much as 22 times the sunlight that it would on the surface of Earth.

**PROBLEM:** How can MESSENGER deal with all the excess sunlight it receives as it travels around Mercury, the closest planet to the Sun?

**Teaching Tip**

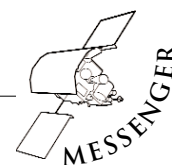
[Here's the answer: 70% of the area of the spacecraft's two solar panels is covered with mirrors, while only 30% has actual solar cells generating energy. In other words, we reduce the unwanted light on MESSENGER by reflecting much of it away and increasing the area from which to radiate away the absorbed excess sunlight.]

**SITUATION:** The MESSENGER spacecraft studying the planet Mercury uses several different instruments to observe the planet. However, there is so much light coming from the Sun and from the surface of the planet that the instruments can receive more light than they can handle.

**PROBLEM:** How can MESSENGER's instruments deal with all the excess light so that they get enough light to make the observations but not so much that it would damage them?

**Teaching Tip**

[Here's the answer: MESSENGER's instruments use baffles – basically fences that limit the amount of sunlight entering the instrument detectors. This is actually a solution very similar to the snow goggles!]





## LESSON ADAPTATIONS

For students with coordination problems, have a team member cut out the goggles.

## EXTENSIONS

Challenge students to design a better pair of goggles. (They may want, for example, an extra, foldable visor for changing light conditions, or to serve as multipurpose goggles that may also protect against UV radiation, wind, glare, etc.)

## CURRICULUM CONNECTIONS

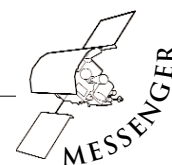
- ▼ *Social Studies*: Find out the history of Inuit hunters, and challenges they faced in dealing with harsh weather, difficult living conditions, limited tools or weapons, and dangers. Research different kinds of snow, ice, light and cold protective gear at different locations around the world.
- ▼ *Mathematics*: Have students complete Student Challenge Worksheet 1 on Field of View.
- ▼ *Technology/Industrial Design*: Have students hypothesize as to the ideal amount of light needed for the eye to distinguish certain details such as water, fire, mountains, craters, metallic objects, etc. in different environments such as in a cave, on an ice sheet, in a desert, or out in space.
- ▼ *Art and Design*: Have students compare the style of snow goggles to other kinds of eye protection used in different professions, and then identify the best elements of each that might be incorporated into a more functional and aesthetically-appealing design.

## ASSESSMENT

Determine whether or not students' observations about the effectiveness of reducing light to the eye can actually improve vision, or if it has any other side effects. Use student worksheets to evaluate level of precision in conducting experiments. See Discussion and Reflection assignment for transfer of knowledge to MESSENGER mission.

Suggested essay questions for tests or take-home exams:

- ▼ Explain why sometimes you need to reduce the amount of sunlight reaching your eyes; describe at least three places where this might be true. Explain what you might have used to protect your eyes in the 19th century, and compare that with what you would use today.





- ▼ List at least three things that are good for you in the right quantity, but that if you have too much of them, they become bad for you. Explain how you would reduce the excess amounts of each, and if your solution is practical or not.
- ▼ Look at pictures of the MESSENGER spacecraft and research it on the Internet. Describe the general conditions in space, and explain which conditions create problems for equipment.
- ▼ Describe the general conditions in space, and, using the scientific method, design solutions to at least two of the problems that prevent humans from easily living there without a great deal of protection and support.

#### CLOSING DISCUSSION

Review with the students situations where excess sunlight can be a problem. Remind students that they have used the scientific method in two different contexts: designing snow goggles for hunters in arctic regions in springtime, and for spacecraft exploring planets close to the Sun. Discuss with the students how the same method can be used in a variety of situations. Review with the students the reasons why the scientific method makes science so robust in providing solutions to a variety of problems.







## INTERNET RESOURCES & REFERENCES

*MESSENGER website*

<http://messenger.jhuapl.edu>

*Alaska Native Heritage Center*

<http://www.alaskanative.net>

*Alutiiq Museum and Archaeological Repository, Kodiak, Alaska*

<http://www.alutiiqmuseum.com>

*A Journey Through Canadian History and Culture: Snow Travel in Ancient Canada*

[http://www.civilization.ca/educat/oracle/modules/iandyck/page01\\_e.html](http://www.civilization.ca/educat/oracle/modules/iandyck/page01_e.html)

*Smithsonian Institution: "Looking both ways," an exhibit of the Smithsonian Museum of Natural History*

<http://www.mnh.si.edu/lookingbothways>

*Smithsonian Museum of Natural History, Arctic Studies Center web resources*

<http://www.mnh.si.edu/arctic/html/resources.html>

*University of Alaska Museum: Artifacts from St. Lawrence Island*

[http://www.uaf.edu/museum/depts/archaeo/pages/gallery/stlwrc\\_01.html](http://www.uaf.edu/museum/depts/archaeo/pages/gallery/stlwrc_01.html)

*National Science Education Standards*

<http://www.nap.edu/html/nse/html/>

*American Association for the Advancement of Science, Project 2061*

<http://www.project2061.org/tools/benchol/bolframe.htm>

# FIELD-OF-VIEW (FOV) WITH AND WITHOUT SNOW GOGGLES

## Materials

Per student:

- ▼ Snow goggle Pattern A or B
- ▼ Scissors

Per group of 3:

- ▼ 2 meter sticks
- ▼ 2 chairs
- ▼ Scotch tape

You will make snow goggles similar to those used by ancient Inuit hunters.

- ▼ Organize into groups, three students per group.
- ▼ Gather materials.

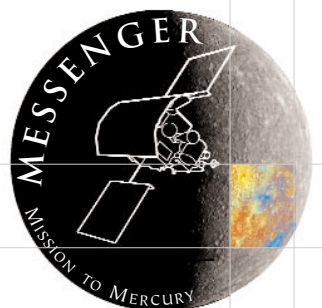
## Procedures

1. Cut out snow goggle patterns and construct them. Make sure your group has one of each pattern.
2. Put the goggles on, making sure to place them so they fit like glasses, resting on the bridge of your nose comfortably, but are not wrapped around your face. Look up and down, right and left. Write your observations below.

3. Now do a scientific experiment. One of the members in your group is the Viewer, another is the Experimenter and the third, the Controller. (You will do the experiment three times so everyone plays each role once.) First, the Viewer puts on his/her goggles, and the group does the following:

a) The Controller sits down in a chair. The Viewer sits down in the other chair 50 cm away and looks the Controller directly in the eyes. The Controller makes sure the Viewer does not move his or her eyes or head through this part of the Experiment.

b) The Experimenter stands to the side of the Viewer and holds up one hand above the Viewer's eye level and the other one below. The Experimenter moves the upper hand slowly higher and the lower hand lower, alternating between the hands. While staring the Controller straight to the eyes, the Viewer tells exactly when (s)he loses sight of the Experimenter's hands. This is the Viewer's vertical Field-of-View (FOV).



c) The Controller uses the meter stick to measure the Experimenter's armspread, and writes down his/her observation here (noting which pattern of snow goggles was used.)

Vertical FOV \_\_\_\_\_ with Pattern \_\_\_\_\_ for student \_\_\_\_\_ (your name here).

d) Repeat b) for horizontal FOV. The Experimenter stands behind the Viewer and places one hand to the right-hand side of the viewer and the other to the left-hand side. While the Experimenter slowly moves his/her hands forward from the Viewer, the Viewer tells exactly when (s)he has sight of them. This range defines the Viewer's horizontal FOV.

e) The Controller uses the meter stick to measure the Experimenter's armspread, and writes down his/her observation here (noting which pattern of snow goggles was used).

Horizontal FOV \_\_\_\_\_ with Pattern \_\_\_\_\_ for student \_\_\_\_\_ (your name here).

4. Repeat (3) but without the Viewer wearing goggles. Write the observations about the FOV here.

Vertical FOV without goggles: \_\_\_\_\_

Horizontal FOV without goggles: \_\_\_\_\_

5. Repeat (3)-(4) for each student in your group, first with the goggles, then without.

6. Based on each Experimenter's notes on 3c), 3e), and 4), discuss as a group your observations and write them here.

Now answer the following questions individually:

1. How did the goggles change your vertical FOV?

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2. How did they affect your side-to-side (horizontal) FOV?

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3. List some advantages of the snow goggles.

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4. List some disadvantages of the snow goggles.

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5. Would covering the goggles with reflective material have an effect?

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6. Do you think the goggles are useful for the hunter in snow-and-ice covered arctic regions? Why or why not?

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7. How would you improve the goggles? (You may want to make an improved version at home and bring them to class next time.)

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8. Which pattern would you rather use if you had to hunt like the ancient Inuits in the snow? Why? (Keep in mind, the bigger your field of view, the more light will enter your eyes.)

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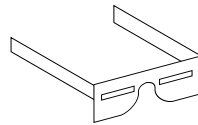
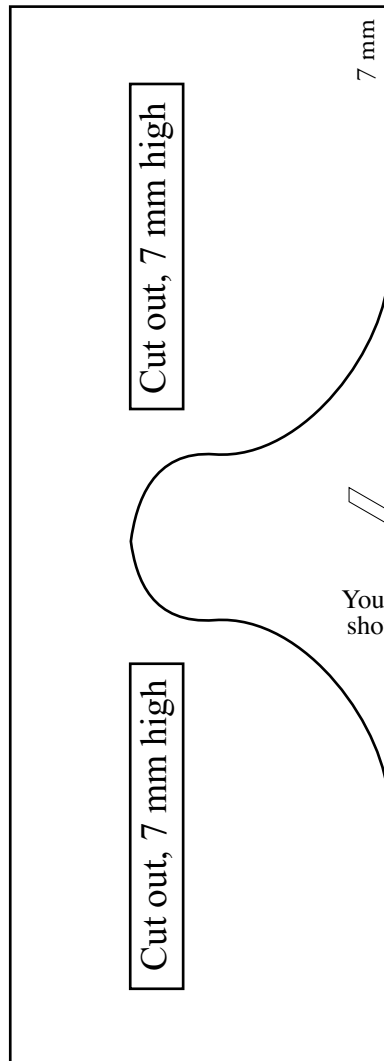
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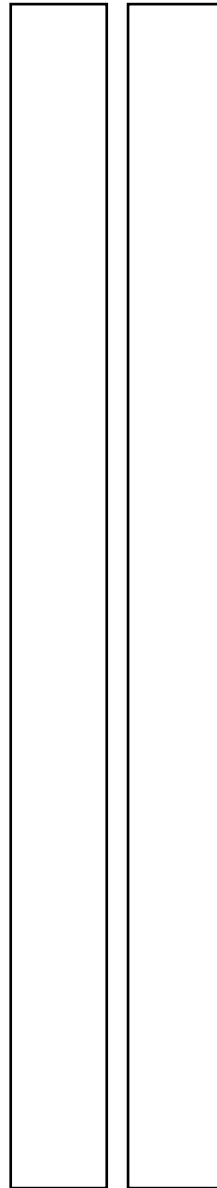


## Snow Goggles: 7 mm Eye Opening

Cut out all pattern parts. Attach earpieces as illustrated below. Adjust to fit like eyeglasses.



Your finished goggles should look like this.

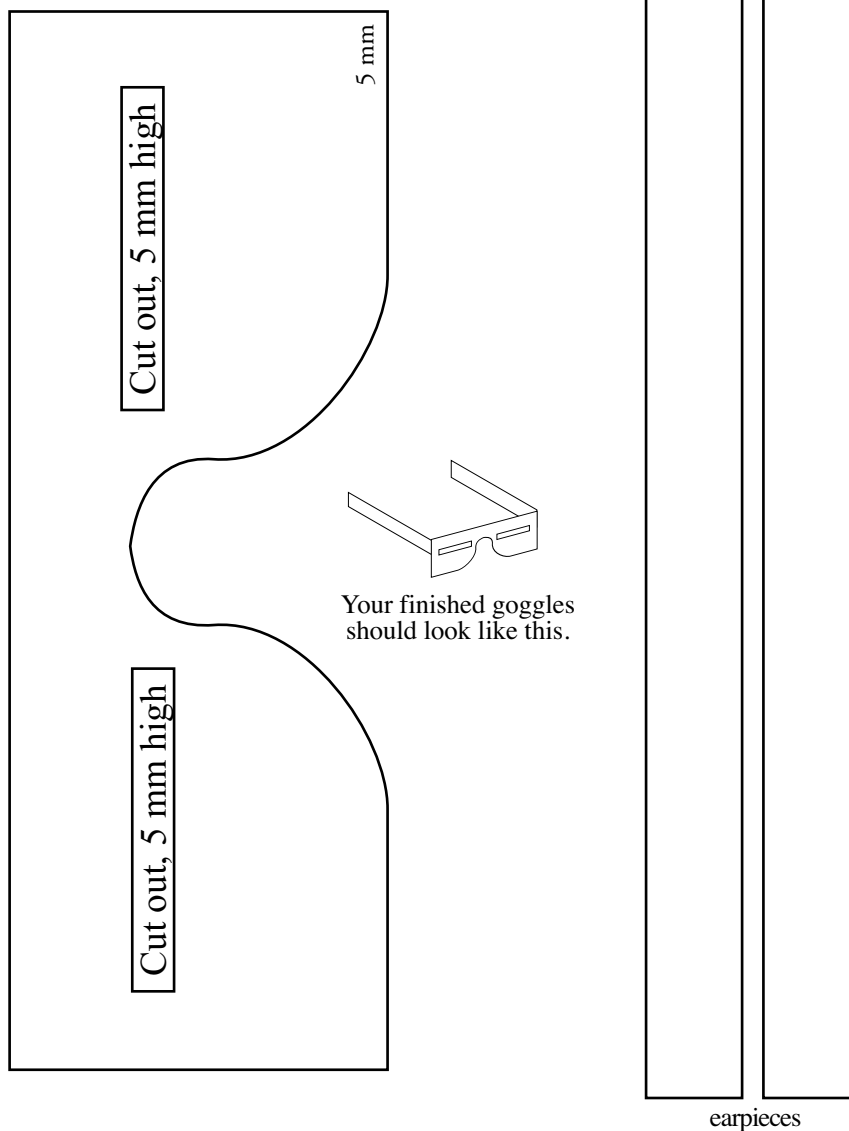


earpieces

For more information about the MESSENGER mission to Mercury, visit:  
<http://messenger.jhuapl.edu/>  
Students' snow goggles designed by Dr. Timothy Livengood

## Snow Goggles: 5 mm Eye Opening

Cut out all pattern parts. Attach earpieces as illustrated below. Adjust to fit like eyeglasses.



For more information about the MESSENGER mission to Mercury, visit:  
<http://messenger.jhuapl.edu/>  
Students' snow goggles designed by Dr. Timothy Livengood

## FIELD-OF-VIEW (FOV) WITH MATH

We now use the FOV measurements from Student Worksheet 1 to calculate the FOV more precisely. If  $x$  marks your FOV (either in horizontal or vertical direction), the FOV can be calculated as

$$\text{FOV} = \frac{x \text{ ("how high you can see")}}{d \text{ ("how far you measured")}}$$

This measures the FOV in units called "radians." To convert to angular degrees, multiply this number by  $180^\circ/\pi$ , where  $\pi = 3.14$ . That is,

$$\text{FOV(degrees)} = \text{FOV(radians)} \times \frac{180}{3.14}$$

Convert your FOV measurements from Student Worksheet 1 to radians and degrees;  $d$  is the distance at which the FOV was measured. If you did the measurement right in front of the viewer, use  $d = 10$  cm.

a) Vertical FOV measurement:  $x = \underline{\hspace{1cm}}$  cm

d = cm

→ Vertical FOV = \_\_\_\_\_ radians

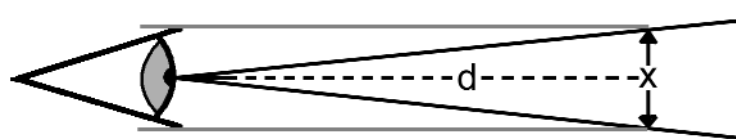
= \_\_\_\_\_ degrees

b) Horizontal FOV measurement:                      x =                      cm

d = \_\_\_\_\_ cm

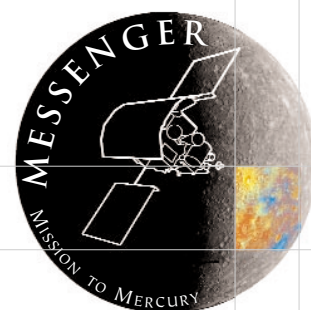
→ Horizontal FOV = \_\_\_\_\_ radians

= \_\_\_\_\_ degrees



$$\text{FOV} = \frac{x}{d} = \frac{\text{how high you can see}}{\text{distance}}$$

Figure S1. The simple formula for Field of View (FOV) – the angle a person can see without moving their eyes or their head.



Fill in the following charts for your group:

**Vertical FOV**

	MINIMUM FOR YOUR GROUP	MAXIMUM FOR YOUR GROUP	AVERAGE OF GROUP
<i>FOV without goggles</i>			
<i>FOV with goggles, Pattern A</i>			
<i>FOV with goggles, Pattern B</i>			

**Horizontal FOV**

	MINIMUM FOR YOUR GROUP	MAXIMUM FOR YOUR GROUP	AVERAGE OF GROUP
<i>FOV without goggles</i>			
<i>FOV with goggles, Pattern A</i>			
<i>FOV with goggles, Pattern B</i>			

Answer the following question individually:

1. Calculate the "reduction factor," that is, how much the goggles reduce the amount of light entering your eyes. This can be estimated by calculating the ratio between by the "area of the world" that you can see (known as "solid angle") without the goggles, and that which you can see with the goggles. Use the FOV results in radians.

Estimate the amount of light entering your eyes without goggles:

$$\begin{aligned}
 \text{Area}_1 &= \text{vertical FOV} \times \text{horizontal FOV} \\
 &= \underline{\hspace{2cm}} \times \underline{\hspace{2cm}} \\
 &= \underline{\hspace{2cm}}
 \end{aligned}$$

Estimate the amount of light entering your eyes with goggles (Pattern \_\_\_\_):

$$\begin{aligned}
 \text{Area}_2 &= \text{vertical FOV} \times \text{horizontal FOV} \\
 &= \underline{\hspace{2cm}} \times \underline{\hspace{2cm}} \\
 &= \underline{\hspace{2cm}}
 \end{aligned}$$

$$\begin{aligned}
 \text{Reduction factor} &= \text{Area}_1 / \text{Area}_2 \\
 &= \underline{\hspace{2cm}}
 \end{aligned}$$





# THE SCIENTIFIC METHOD IN ACTION

Remember that in constructing the snow goggles and experimenting with their FOV, we used the scientific method:

A scientist:

- 1) states a problem;
- 2) forms a hypothesis;
- 3) experiments;
- 4) observes the results of an experiment;
- 5) revises the hypothesis or concludes that it is acceptable.

A. Read the MESSENGER Information Sheet.

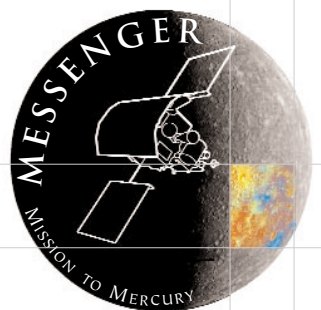
B. Now, let's imagine the following:

**SITUATION ONE:** The MESSENGER spacecraft flying to the planet Mercury uses solar cells to generate electricity. However, as the spacecraft gets closer to the Sun, it receives more sunlight than it can handle. Smaller solar cells are not the answer, since the Sun still heats up the cells. MESSENGER will be exposed to 22 times the sunlight that it would on the surface of Earth.

**PROBLEM ONE:** How can MESSENGER deal with all the excess sunlight it receives as it travels around Mercury, the closest planet to the Sun?

**SITUATION TWO:** The MESSENGER spacecraft studying the planet Mercury uses several different instruments to observe the planet. However, there is so much light coming from the Sun and from the surface of the planet that the instruments can receive more light than they can handle.

**PROBLEM TWO:** How can MESSENGER's instruments deal with all the excess light so that they get enough light to make the observations but not so much that it would damage them?



C. Use steps one and two of the scientific method to come up with ways to overcome these problems.

Write your notes below.

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D. Sometimes we cannot do hands-on laboratory experiments to test our hypothesis. One way that scientists test hypotheses is by computer simulations. Another way is to think of all possible situations the suggested solution could encounter and see whether it would stand up to them. We use this last approach here in the next steps.

E. State your problem and hypothesis. Have other students comment and suggest alternatives. These simulated experiments now take the place of real-life experiments.

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F. Once you have thought things through, consider: Do you want to revise your hypothesis? If so, write revisions below. Otherwise, accept your solution, and explain why.

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*The teacher will tell you the MESSENGER mission designers' solution to the problem. How does their solution compare with yours?*





## ANSWER KEY

Sample answers to Student Worksheet Questions:

### Student Worksheet 1

1. *How did the goggles change your vertical FOV?*

The goggles made the vertical FOV a lot smaller.

2. *How did they affect your side-to-side (horizontal) FOV?*

The goggles did not significantly reduce the side-to-side [horizontal] FOV. Slits and construction styles may cause answers to vary.

3. *List some advantages of the snow goggles.*

Advantages include increased comfort level while looking at bright areas, ability to look longer in bright areas, improved visibility of specific objects.

4. *List some disadvantages of the snow goggles.*

Disadvantages include problems of seeing nearby objects, the need to move one's head or eyes more often to see potential threats – both stationary such as low branches, trenches or sharp objects in your path, and moving things, such as a hungry polar bear lumbering towards you.

5. *Would covering the goggles with reflective material have an effect?*

They should not, since the goggles work by reducing the amount of light entering the viewer's eyes, and light hitting the opaque goggles does not go through whether they are covered by reflective material or not. (Note that reflective material could help keep snow goggles from overheating by reflecting much of the sunlight striking them instead of having it absorbed, but in the cold, arctic springtime, overheating is not usually a big problem.)

6. *Do you think the goggles are useful for the hunter in snow-and-ice covered arctic regions? Why or why not?*

The goggles would work well, since they reduce the amount of sunlight and glare entering the eyes from above and below while allowing you to scan your environment horizontally without moving your head.





7. *How would you improve the goggles?*

Students may want to make the goggles from sturdier material, reduce or increase slit size, etc. Observe the goggles that students design.

8. *Which pattern would you rather use if you had to hunt like the ancient Inuits in the snow? Why?*

Students may wish to use the 5mm pattern to reduce the amount of light entering their eyes, or the 7mm pattern to increase their field of view. This is the correct reasoning for choosing between the slit sizes, but which size the students choose to use depends on the individual person's preference, and there is no "correct" answer to this question.

### **Student Challenge Worksheet 1**

#### *Group questions*

1. Answers will vary depending on exactly how the experiment was done and the student's individual FOV.
2. Answers on charts will vary corresponding to the measurements.

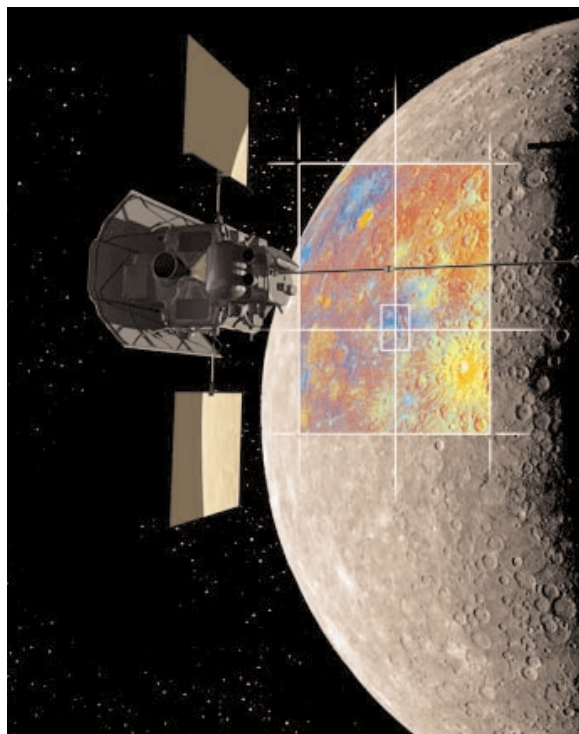
#### *Individual questions*

1. *Calculate the "reduction factor," ( $\text{Area}_1 / \text{Area}_2$ )*

The reduction factor is expected to be roughly 3-4. This means that your unprotected eyes receive 3-4 times more light than when you wear the protective snow goggles. Students' answers may vary because of measurement errors, differing visions among students, etc.



## MESSENGER INFORMATION SHEET



### *The MESSENGER Mission to Mercury*

MESSENGER is an unmanned U.S. spacecraft that will be launched in 2004 and will arrive at the planet Mercury in 2009, though it will not land. Instead, it will make its observations of the planet from orbit. MESSENGER will never return to Earth, but will stay in orbit around Mercury to gather data until sometime in 2010.

MESSENGER is an acronym that stands for "MErcury Surface Space ENvironment, GEochemistry and Ranging," but it is also a reference to the name of the ancient Roman messenger of the gods: Mercury, who, it was said, wore winged sandals and was somewhat of a trickster.

MESSENGER will be the second spacecraft ever to study Mercury: In 1974 and 1975 Mariner 10 flew by the planet three times and took pictures of about half the planet's surface. MESSENGER will stay in orbit around Mercury for about one Earth-year, during which time it will make close-up and long-term observations, allowing us to see the whole planet for the first time.

Because Mercury is so close to the Sun, one of the biggest problems the spacecraft will encounter is intense sunlight, which will be 11 times as high as in space near Earth and 22 times as high as on the surface of Earth. It is a big concern for the instruments used to observe Mercury, because they can get so much sunlight that they get blinded. Sunlight is also a concern for the solar cells that the spacecraft uses to generate electricity. The same kind of solar cells you may have seen on Earth would normally cover the whole area of the spacecraft's solar panels facing the Sun. But in the case of MESSENGER, the solar cells heat up faster than they can cool down (panels usually cool off by radiating away excess heat out the back and sides). So MESSENGER engineers had to come up with a solution for keeping the solar cells from heating up too much and for keeping the sensitive instruments from getting blinded. (Perhaps you will find the answer currently being used. If not, ask your teacher, or think of a better way!)

